APPLICATION NOTE

Los Alamos National Laboratory
A Department of Energy Laboratory

The ^{252}Californium Shuffler

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Safeguards Assay Group (N-1)

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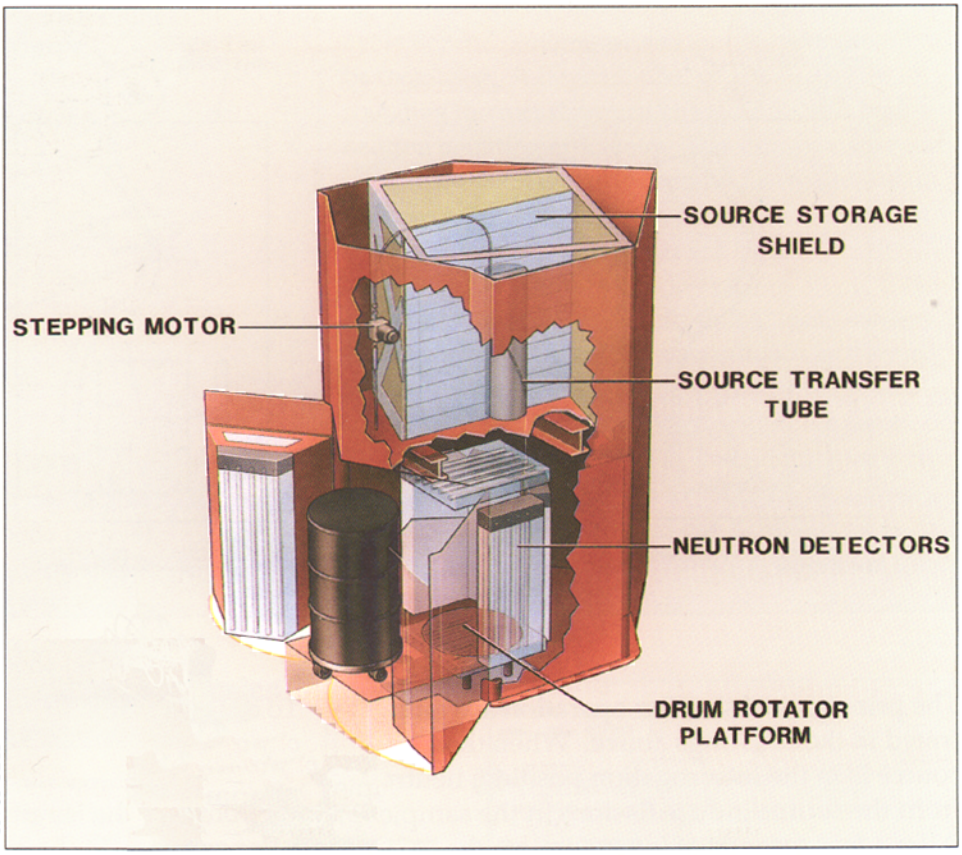

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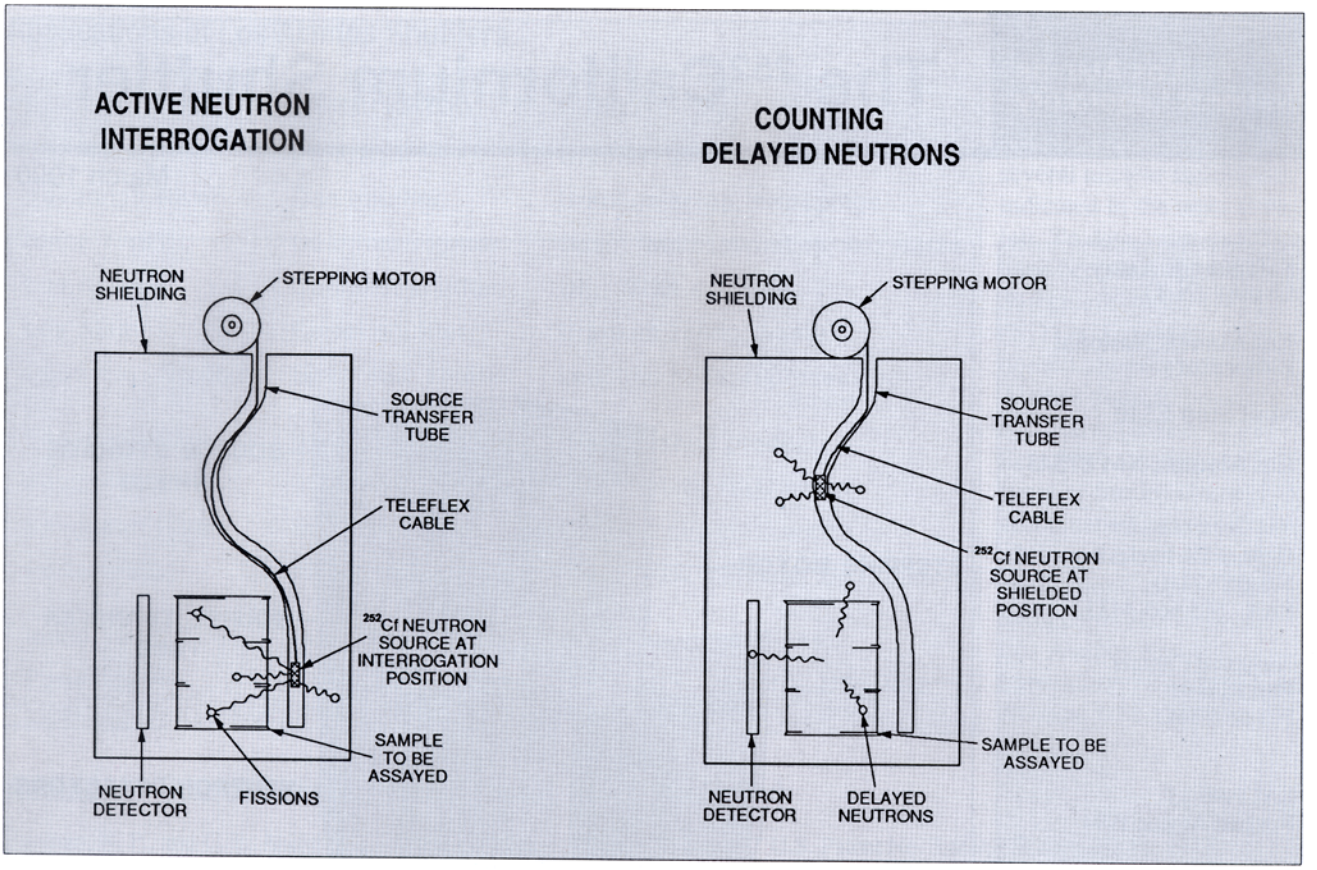
The californium shuffler shown above measures the nuclear material in a barrel of waste (black) by irradiating the waste with neutrons from a ^{252}Cf source and then pulling the source back into the shielding (light blue with horizontal stripes). The barrel is surrounded with ^{3}He tubes (light blue with grey tops) that count the delayed neutrons from the irradiated barrel.

The ^{252}Cf shuffler is a versatile nondestructive assay (NDA) instrument that has been used for measuring uranium in a wide variety of forms, ranging from large spent fuel assemblies to small amounts of scrap and waste. Shufflers are relatively insensitive to measurement bias caused by matrix materials and consequently provide one of the most accurate methods available for measuring uranium waste. Because of ruggedized design and reliability of components, shufflers are well suited for plant operating conditions.



The principles of shuffler operation are illustrated in the drawings above. When the ^{252}Cf source is in the interrogation position, neutrons from the source induce fissions in the sample. After a few seconds of interrogation, the ^{252}Cf source is quickly removed to a shielded position, and delayed neutrons emitted by fission fragments are counted. The number of delayed neutrons emitted is proportional to the amount of fissionable material present in the sample. The cycle of interrogation and delayed neutron counting can be repeated many times to obtain good statistical precision. The shuffler design shown in the cut-away drawing on the cover was optimized for measuring 55-gallon waste barrels.

To obtain a more uniform response from nuclear materials at different locations in the barrel, the shuffler rotates the barrel and the ^{252}Cf source scans the length of the barrel during interrogation. In the active mode, the shuffler responds to all fissionable isotopes present in the sample. By shielding the ^{252}Cf source exceptionally well, shuffler hardware can also serve as a passive neutron counter. Passive neutron coincidence counting is used to assay spontaneously fissioning isotopes such as ^{240}Pu. Following this approach, new active/passive barrel shufflers are capable of measuring small amounts of ^{235}U in the active mode and ^{240}Pu in the passive mode.

Active-Passive Barrel Shuffler Characteristics

^{252}Cf Source and Shield

- Source strength: 8 x 10^8 n/s
- Source half-life: 2.6 yr
- Radiation shielding: 2 tons
- Radiation level:
  1 mR/h at 1 m from source shield
- Irradiation cycle: 11 s
- Count cycle: 7 s
- Source transfer time: 0.4 s

Sample Chamber

- Detectors: 64 ^{3}He tubes
- Detection efficiency: 17.5%
- Radiation shielding: 4 tons
- Barrel rotation speed: 3 rpm
- Liner: cadmium
- Inside diameter: 30 in.

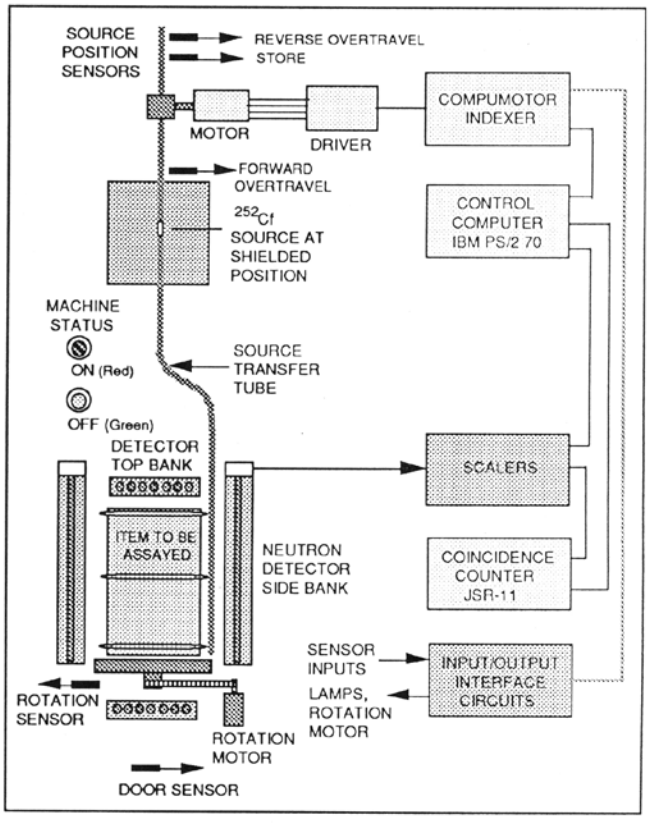
Measurement Capability

- Measurement time: 1000 s
- ^{235}U detection sensitivity (active): 300 mg
  —in thermal mode (active): 20 mg
- ^{240}Pu detection sensitivity (passive): 4 mg
- Accuracy: 15% for waste barrels

Active/passive barrel shuffler characteristics are shown in the table at the left. A ^{252}Cf source of 0.35 mg emits 8x10^8 neutrons per second. Shielding (consisting of tungsten, high-density polyethylene, and boron-loaded polyethylene) is used to limit the radiation dose rate outside the shuffler. The optimum interrogation time and count time for each cycle depend on the type and amount of material to be measured. A large number of ^{3}He tubes surrounding the measurement chamber gives a high neutron counting efficiency. Detection sensitivities quoted in the table correspond to the smallest mass of bare material that gives a count rate 3 sigma above neutron background at sea level. The ^{235}U detection sensitivity can be lowered to 20 mg if the cadmium liner is removed from the measurement chamber so that neutron interrogation is performed in the thermal mode. Accuracy depends on the distribution of fissionable material within the barrel, on the effect of matrix materials, and on the suitability of the NDA standards used to calibrate the instrument. For waste barrels that can be separated by type of matrix, the assay accuracy is estimated to be plus or minus 15% (1 sigma).

Shuffler Electronics

The block diagram at the right shows the electronic components of an active/passive shuffler. The ^{252}Cf source is attached to a Teleflex cable, which is driven by a stepping motor. Safety sensors verify the position of the source and ensure that the doors are closed before the source is lowered into the measurement chamber. Instrument operation is controlled by a small computer. Software provides measurement control, routine assay, and data archiving.



Applications of Los Alamos Shufflers

Location	Description	Material Type
Los Alamos	Prototype	Uranium solids, MOX, U ore
Savannah River	Can shuffler	Uranium scrap, sweepings
Idaho FAST	Dual interrogator	Spent fuel assemblies, hot waste
Los Alamos	Compact shuffler	UF_6, MOX samples
Los Alamos	Barrel shuffler	Uranium solids, waste
Dounreay, Scotland	Spent fuel shuffler	Leached hulls, reprocessing waste
Savannah River	In-cabinet shuffler	HEU finished product
Savannah River	In-cabinet shuffler	High-density HEU scrap
Savannah River	Barrel shuffler	High-density HEU waste
Portsmouth	Active/passive barrel shuffler	HEU >20%, alumina, UF_6, tails
Idaho WINCO	In-line shuffler	Hot uranium solutions
Portsmouth	Active/passive barrel shuffler	HEU <20%, alumina, UF_6, tails

Shufflers have been designed for a wide variety of applications and used at several nuclear facilities as indicated in the table at the left. To date, most shufflers have been built by the Safeguards Assay Group (N-1) at Los Alamos National Laboratory. Los Alamos plans to procure two active/passive shufflers from a commercial supplier for local materials accountancy programs. For advice on specific shuffler applications, contact the Safeguards Assay Group, Los Alamos National Laboratory, MS E540, Los Alamos, NM 87545.

Additional Sources of Information (listed chronologically)

Bauman, N. P., and C. E. Ahlfeld, "Oscillating Monitor for Fissile Material," U.S. Patent No. 3,699,338, October 17, 1972.

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